

Application No. 10/634,636  
37 C.F.R. § 1.312 amendment

page 3 of 13  
January 20, 2006

**Listing of Claims:**

1 – 2. (Cancelled)

3. A trapped charge memory device comprising:

a top electrode;

a bottom electrode; and

a trapped charge memory body sandwiched between and in electrical contact with said top electrode and said bottom electrode, defining both a top electrode to trapped charge memory body contact and a bottom electrode to trapped charge memory body contact;

wherein said trapped charge memory device contains current carrier traps that influence said trapped charge memory device's voltage switchable resistance  $R_d$ ;

whereby said influence of  $R_d$  is accomplished with energy levels of said current carrier traps, degrees of carrier occupancy or concentration of said current carrier traps, or some combination thereof

wherein said current carrier traps comprises hole traps.

4. The trapped charge memory device of claim 3 wherein said current carrier traps are characterized by at least one energy level within a bandgap between a conduction band and a valence band of said trapped charge memory body for trapping current carriers.

5. The trapped charge memory device of claim 3 wherein the energy levels and respective degrees of carrier occupancy of said current carrier traps are selected such that said trapped charge memory device, while under a variable drive voltage of  $V_d$

Application No. 10/634,636  
37 C.F.R. § 1.312 amendment

page 4 of 13  
January 20, 2006

applied between said top electrode and said bottom electrode, exhibiting M voltage switchable levels of resistance values  $R_1, R_2, \dots, R_M$  in the following manner:

$R_d = R_j$  when  $-VN_{cj} \leq V_d \leq +VP_{cj}$ ; and

$R_d$  switches to  $R_{j+1}$  when  $V_d$  goes above  $+VP_{cj}$  followed by  $R_d$  switching back to  $R_j$  when  $V_d$  then drops below  $-VN_{cj}$

where  $M \geq 2$ ,  $j = (1, 2, \dots, M-1)$  and each of  $VP_{cj}$  and  $VN_{cj}$  are positive voltage magnitudes.

6. The trapped charge memory device of claim 5 wherein  $VP_{cj}$  is essentially equal to  $VN_{cj}$  for at least one value of the index  $j$  whereby the corresponding switching of  $R_d$  between  $R_j$  and  $R_{j+1}$  uses a symmetric bipolar drive operation in the voltage domain.

7. The trapped charge memory device of claim 5 wherein the resistance switching time, between members of the resistance values  $R_1, R_2, \dots$  and  $R_M$ , of said  $R_d$  is from about 0.1 ns to about 100  $\mu$ s.

8. The trapped charge memory device of claim 3 wherein at least one of the top electrode-to-trapped charge memory body contact and the bottom electrode-to-trapped charge memory body contact is made non-ohmic, whereby said  $R_d$  exhibits a corresponding degree of nonlinearity.

9. The trapped charge memory device of claim 3 wherein said  $R_d$  is a function of the total charge, called trapped charges, carried by trapped current carriers at said current carrier traps.

Application No. 10/634,636  
37 C.F.R. § 1.312 amendment

page 5 of 13  
January 20, 2006

10. The trapped charge memory device of claim 9 wherein the amount of trapped charges is modifiable by the height and width of a write voltage pulse applied across said top electrode and said bottom electrode.

11. The trapped charge memory device of claim 9 wherein the amount of trapped charges is modifiable by a mechanism of carrier tunneling.

12. The trapped charge memory device of claim 9 wherein the amount of trapped charges is modifiable by a mechanism of free carrier capturing.

13. (Cancelled)

14. The trapped charge memory device of claim 3 wherein said  $R_d$  is a function of current carrier traps located within two Schottky junctions respectively defined by said top electrode-to-trapped charge memory body contact and said bottom electrode-to-trapped charge memory body contact.

15. The trapped charge memory device of claim 14 wherein said current carrier traps acts, depending upon their charge type, to alter the barrier height of said Schottky junctions thus effecting a corresponding change of  $R_d$ .

16. The trapped charge memory device of claim 3 wherein said  $R_d$  is a function of current carrier traps located near any of said top electrode-to-trapped charge

Application No. 10/634,636  
37 C.F.R. § 1.312 amendment

page 6 of 13  
January 20, 2006

memory body contact or said bottom electrode-to-trapped charge memory body contact that is a Schottky junction.

17. The trapped charge memory device of claim 16 wherein said current carrier traps acts, depending upon their charge type, to alter the barrier height of said Schottky junction thus effecting a corresponding change of  $R_d$ .

18. The trapped charge memory device of claim 3 wherein most of said current carrier traps are located near said top electrode.

19. The trapped charge memory device of claim 3 wherein most of said current carrier traps are located near said bottom electrode.

20. The trapped charge memory device of claim 3 wherein most of said current carrier traps are located near either said top electrode or said bottom electrode.

21 - 25. (Cancelled)

26. The trapped charge memory device of claim 3 wherein said  $R_d$  is a function of those current carrier traps capable of effecting a trap-hopping type of conduction mechanism.

27. The trapped charge memory device of claim 3 wherein said  $R_d$  is a function of those current carrier traps capable of effecting a Frenkel-Poole type of conduction mechanism.

Application No. 10/634,636  
37 C.F.R. § 1.312 amendment

page 7 of 13  
January 20, 2006

28. The trapped charge memory device of claim 3 wherein said  $R_d$  is a function of those current carrier traps capable of disrupting the preferred direction of an ordered pattern of the electron orbitals within a crystal lattice of said trapped charge memory body.

29. The trapped charge memory device of claim 3 wherein said  $R_d$  is a function of those current carrier traps capable of affecting an electron tunneling mechanism.

30. The trapped charge memory device of claim 3 wherein said current carrier traps are created within said trapped charge memory body with the addition of a dopant.

31. The trapped charge memory device of claim 30 wherein said trapped charge memory body is made of a crystalline structure and said dopant material is substitutionally fit into said crystalline structure.

32. The trapped charge memory device of claim 30 wherein said trapped charge memory body is made of a crystalline structure and said dopant material is interstitially fit into said crystalline structure.

33. The trapped charge memory device of claim 30 wherein said dopant material is implemented as separate physical clusters within said trapped charge memory body material.

Application No. 10/634,636  
37 C.F.R. § 1.312 amendment

page 8 of 13  
January 20, 2006

34 - 35. (Cancelled)

36. The trapped charge memory device of claim 3 wherein said trapped charge memory body comprises a poly-crystalline material and said current carrier traps are created at the grain boundaries of said poly-crystalline material.

37. The trapped charge memory device of claim 3 wherein said trapped charge memory body is a layer of thickness between about 100Å and about 5000Å.

38. A method of making a 2-terminal trapped charge memory device with voltage switchable multi-level resistance  $R_d$  and having a top electrode, a bottom electrode and a trapped charge memory body sandwiched between and in electrical contact with said top electrode and said bottom electrode defining a top electrode-to-trapped charge memory body contact and a bottom electrode-to-trapped charge memory body contact, said trapped charge memory body containing current carrier traps with at least one of whose energy levels, respective degrees of carrier occupancy and concentration determine said  $R_d$ , the method comprising:

providing a substrate;

forming a bottom electrode layer atop said substrate;

forming a trapped charge memory body layer atop and in electrical contact with said bottom electrode layer; and

forming a top electrode layer atop and in electrical contact with said trapped charge memory body layer

wherein said current carrier traps comprises hole traps.

Application No. 10/634,636  
37 C.F.R. § 1.312 amendment

page 9 of 13  
January 20, 2006

39. The method of making a 2-terminal trapped charge memory device of claim 38 further comprising creating current carrier traps within said trapped charge memory body through a conditioning procedure.

40. The method of making a 2-terminal trapped charge memory device of claim 39 wherein said conditioning procedure imparts said current carrier traps with a desired degree of carrier occupancy.

41. The method of making a 2-terminal trapped charge memory device of claim 40 wherein said conditioning procedure includes high energy radiation, particle beam bombardment or an electrical initialization process.

42. The method of making a 2-terminal trapped charge memory device of claim 41 wherein said high energy radiation includes exposing the trapped charge memory device with X-ray or UV light.

43. The method of making a 2-terminal trapped charge memory device of claim 41 wherein said electrical initialization process includes exposing the trapped charge memory device with an electrical field.

44. The method of making a 2-terminal trapped charge memory device of claim 38 wherein one or both of the top electrode-to-trapped charge memory body contact and the bottom electrode-to-trapped charge memory body contact are made non-ohmic to create a corresponding nonlinearity of  $R_d$ .

Application No. 10/634,636  
37 C.F.R. § 1.312 amendment

page 10 of 13  
January 20, 2006

45. The method of making a 2-terminal trapped charge memory device of claim 38 wherein said trapped charge memory body layer is made of a semiconducting material of single-crystalline, poly-crystalline or amorphous structure.

46. The method of making a 2-terminal trapped charge memory device of claim 39 wherein the conditioning procedure is performed after the top electrode is formed.

47. The method of making a 2-terminal trapped charge memory device of claim 46 wherein said conditioning procedure imparts said current carrier traps with a desired degree of carrier occupancy.

48. The method of making a 2-terminal trapped charge memory device of claim 47 wherein said conditioning procedure includes high energy radiation, particle beam bombardment or an electrical initialization process.

49. The method of making a 2-terminal trapped charge memory device of claim 48 wherein said high energy radiation includes exposing the trapped charge memory device with X-ray or UV light.

50. The method of making a 2-terminal trapped charge memory device of claim 48 wherein said electrical initialization process further comprises exposing the trapped charge memory device with an electrical field.



Application No. 10/634,636  
37 C.F.R. § 1.312 amendment

page 11 of 13  
January 20, 2006

51. The method of making a 2-terminal trapped charge memory device of claim 46 wherein one or both of the top electrode-to-trapped charge memory body contact and the bottom electrode-to-trapped charge memory body contact are made non-ohmic to create a corresponding nonlinearity of  $R_d$ .

52. The method of making a 2-terminal trapped charge memory device of claim 46 wherein said trapped charge memory body layer is made of a semiconducting material of single-crystalline, poly-crystalline or amorphous structure.

53. The method of making a 2-terminal trapped charge memory device of claim 39 wherein the conditioning procedure is performed after the top electrode is formed and the conditioning procedure imparts said current carrier traps with a desired degree of carrier occupancy.

54. The method of making a 2-terminal trapped charge memory device of claim 53 wherein the charge conditioning procedure includes exposure of the trapped charge memory device to UV light.

55. The method of making a 2-terminal trapped charge memory device of claim 53 wherein the charge conditioning procedure includes exposure of the trapped charge memory device to an electric current.

56. The method of making a 2-terminal trapped charge memory device of claim 53 wherein the charge conditioning procedure includes exposure of the trapped charge memory device to an electric field.